

NA61  
Hadro-production for Neutrino  
Experiments

Geoffrey Mills

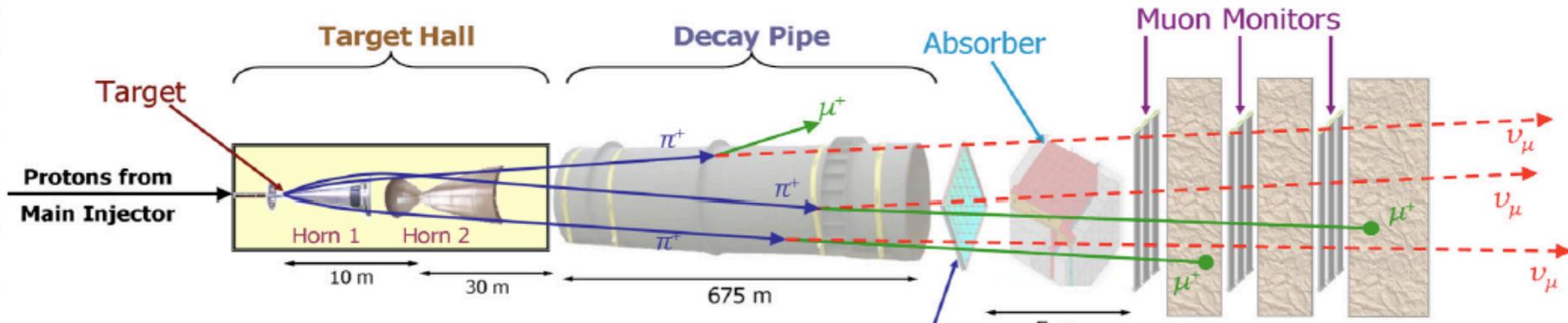
USNA61

August 8, 2013

# Fermilab Neutrino Program

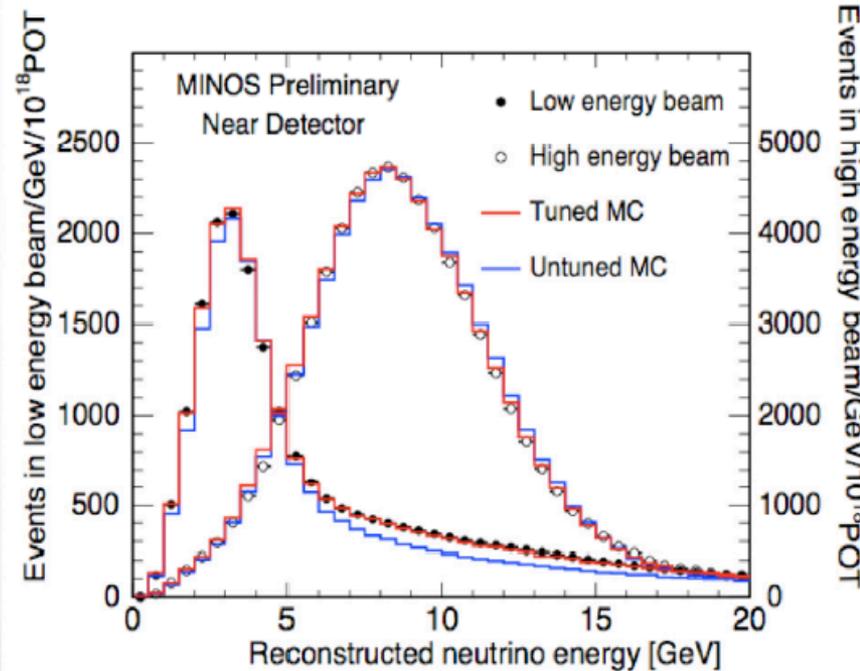
- 120 GeV primary proton beam:
  - MINOS
    - On-axis Far-Near ratio oscillation measurement, graphite target
  - Minerva
    - Cross section measurements, graphite target
  - Nova:
    - Off-axis Far-Near ratio oscillation measurement, graphite target
  - LBNE
    - On-axis oscillation measurement, graphite target

# Ex. NuMI Neutrino Beamline

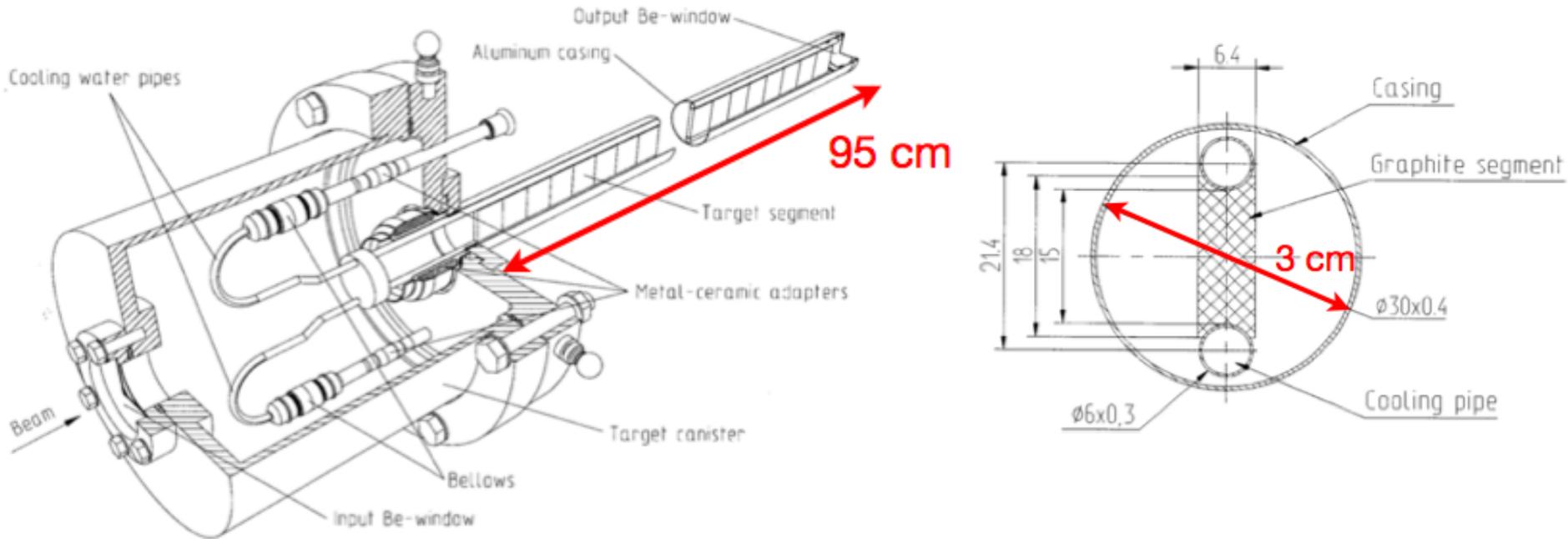


- 120 GeV Protons from Main Injector impinge on a graphite target to produce  $\pi$ , K
- Beam energy spectrum can be modified by varying the relative positions of target and horns
- Most data taken in the “Low Energy” configuration, which optimizes L/E for the measurement of  $\Delta m^2_{\text{atm}}$
- Beam composition in the LE configuration:

91.8%  $\nu_\mu$ , 6.9%  $\bar{\nu}_\mu$ , 1.3%  $\nu_e + \bar{\nu}_e$



# Ex. NuMI Target



- Rectangular shape 6.4mm X 15 mm
- Metal cooling pipes
- 0.4mm thick aluminum sheath

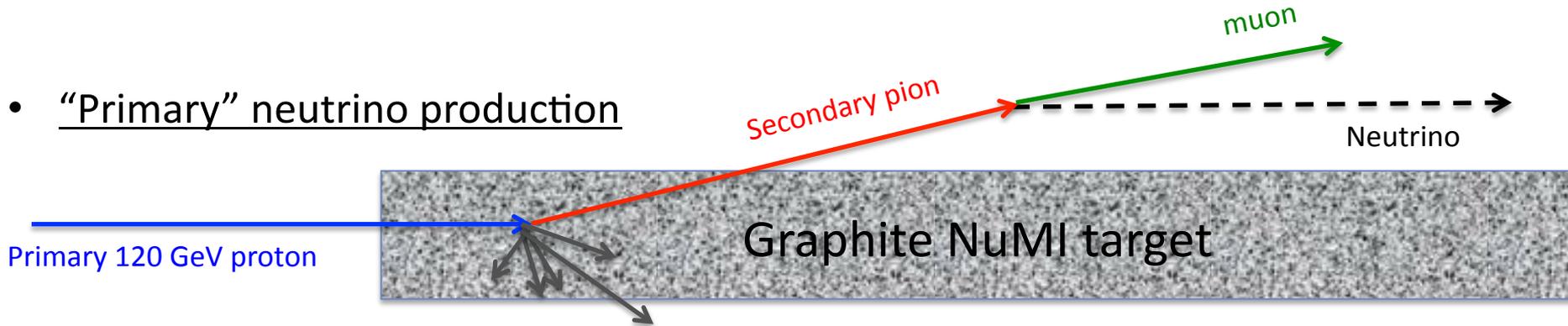
(from D. Schmitz)

# Hadron Production

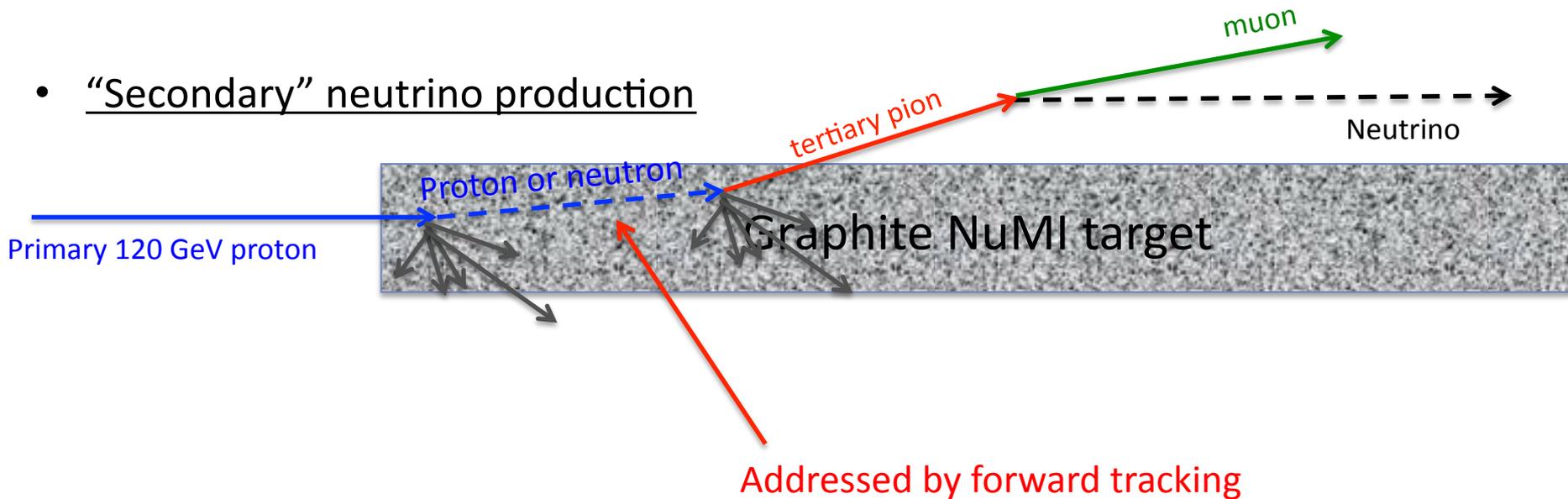
- Typically the largest source of uncertainty in neutrino flux predictions for “wide-band” (horn focused) beams
- It is not obvious why this is the case, but clearly there is no first-principle calculation for hadron production
- Currently empirical models (scaling) are used
  - They are only as good as the input data
  - Extrapolation errors are difficult to control

# Neutrino Production

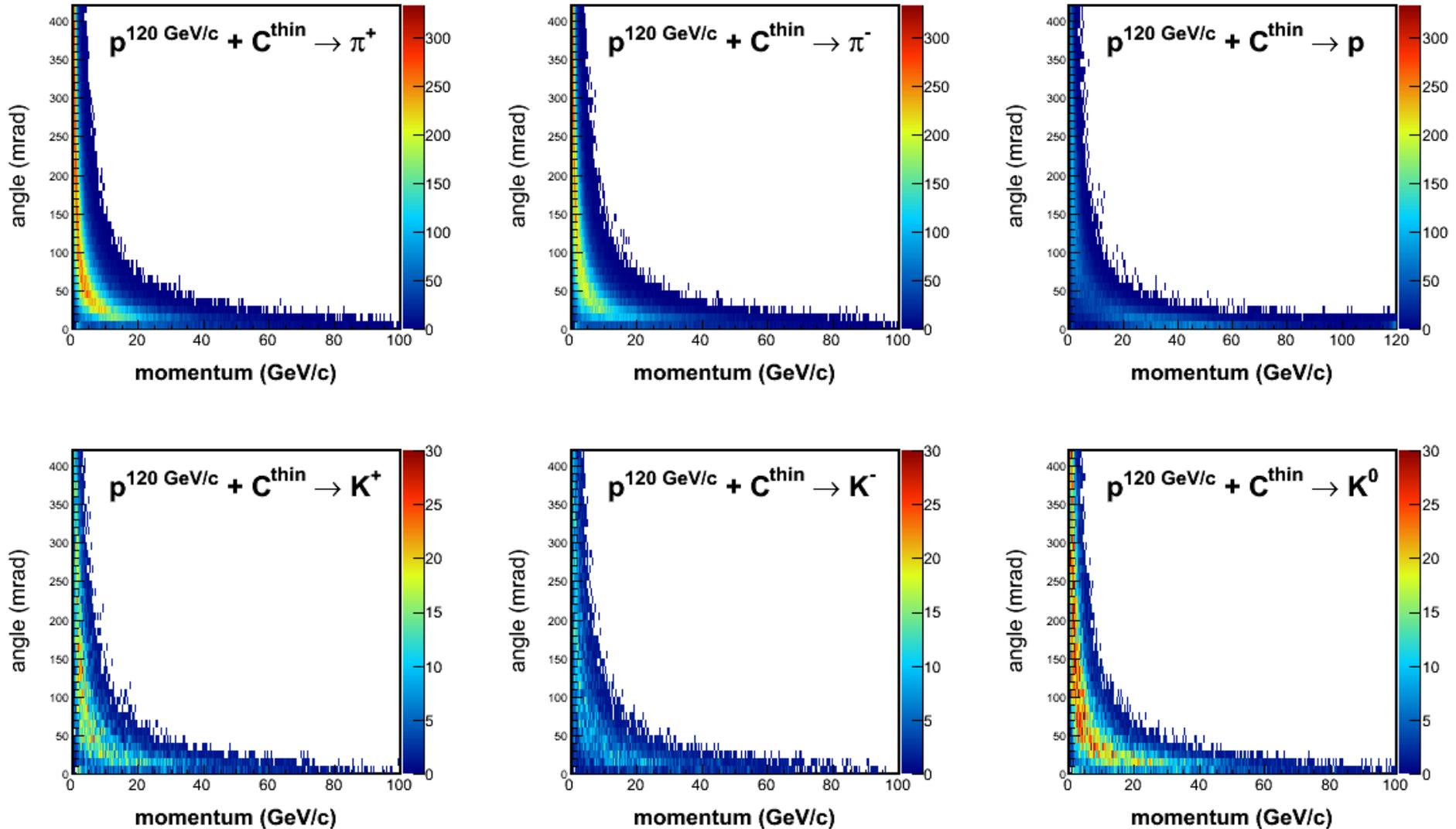
- “Primary” neutrino production



- “Secondary” neutrino production



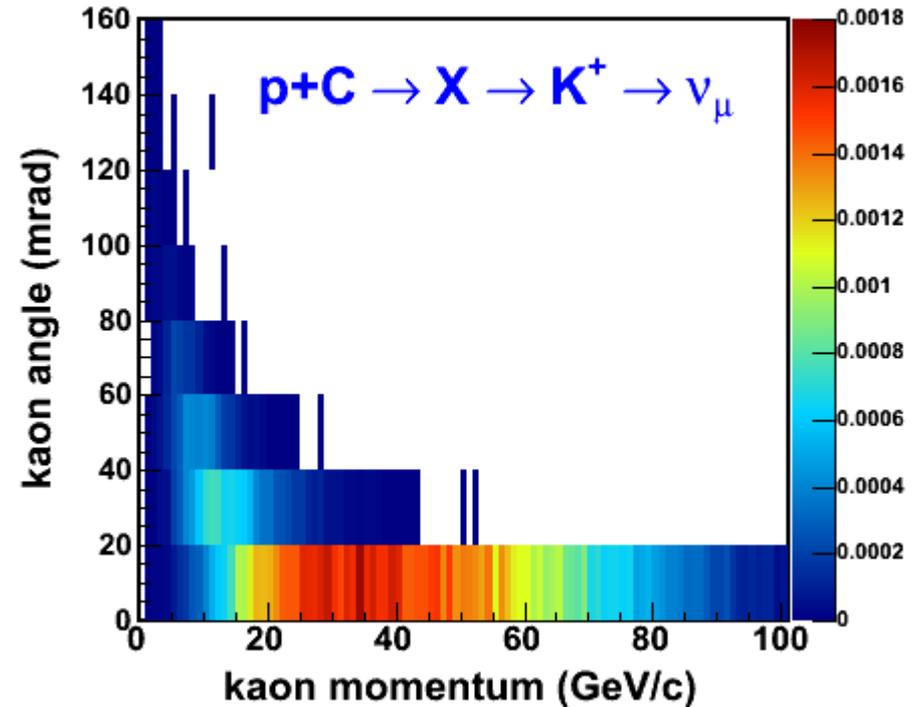
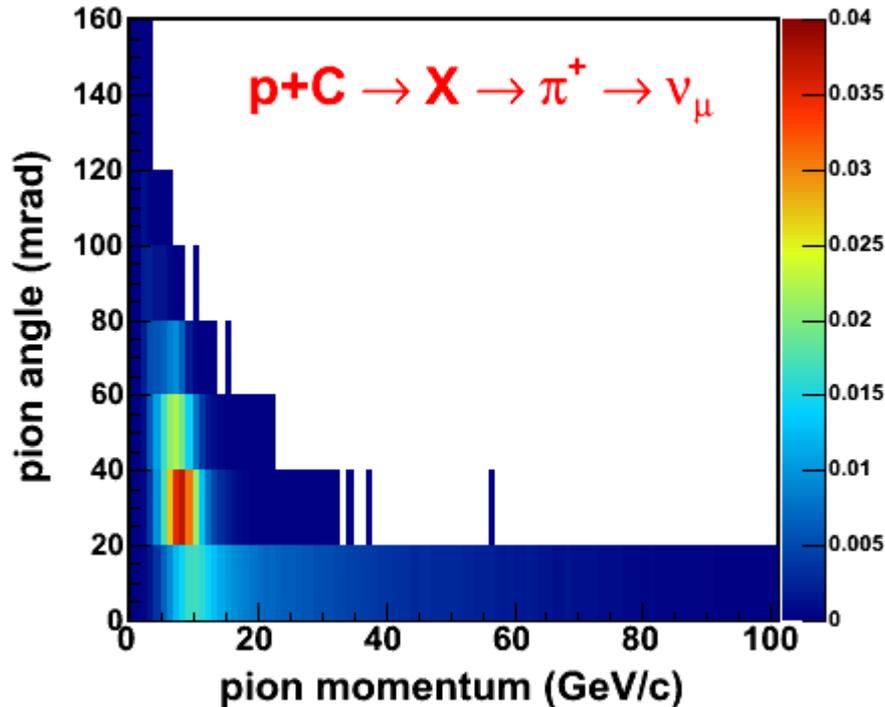
# Particle Production Spectra from MC



(from D. Schmitz)

\*MC samples (thin/thick, pion/proton) all generated by Leo Aliaga

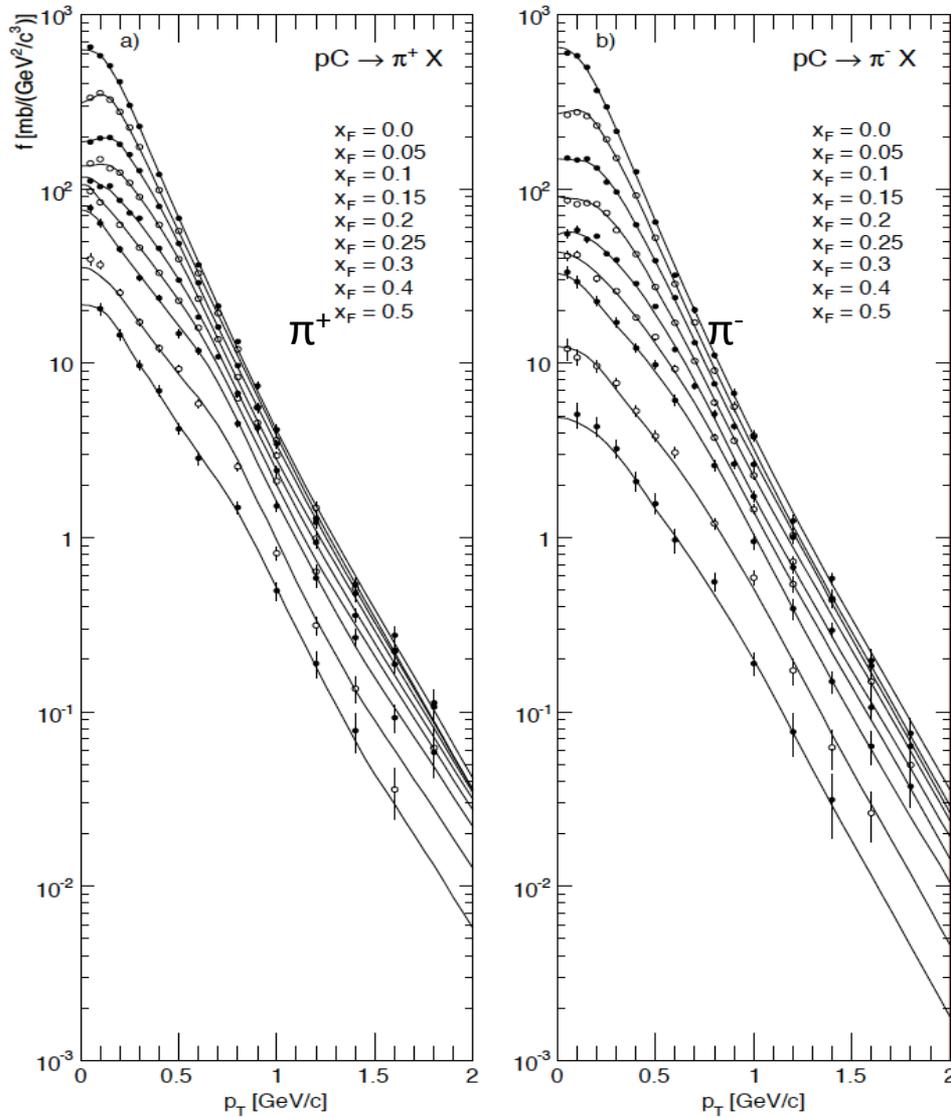
# NuMI Meson Parent Kinematics



- Pions and kaons coming out of the target structure that create a  $\nu_\mu$  in NuMI Near Detector

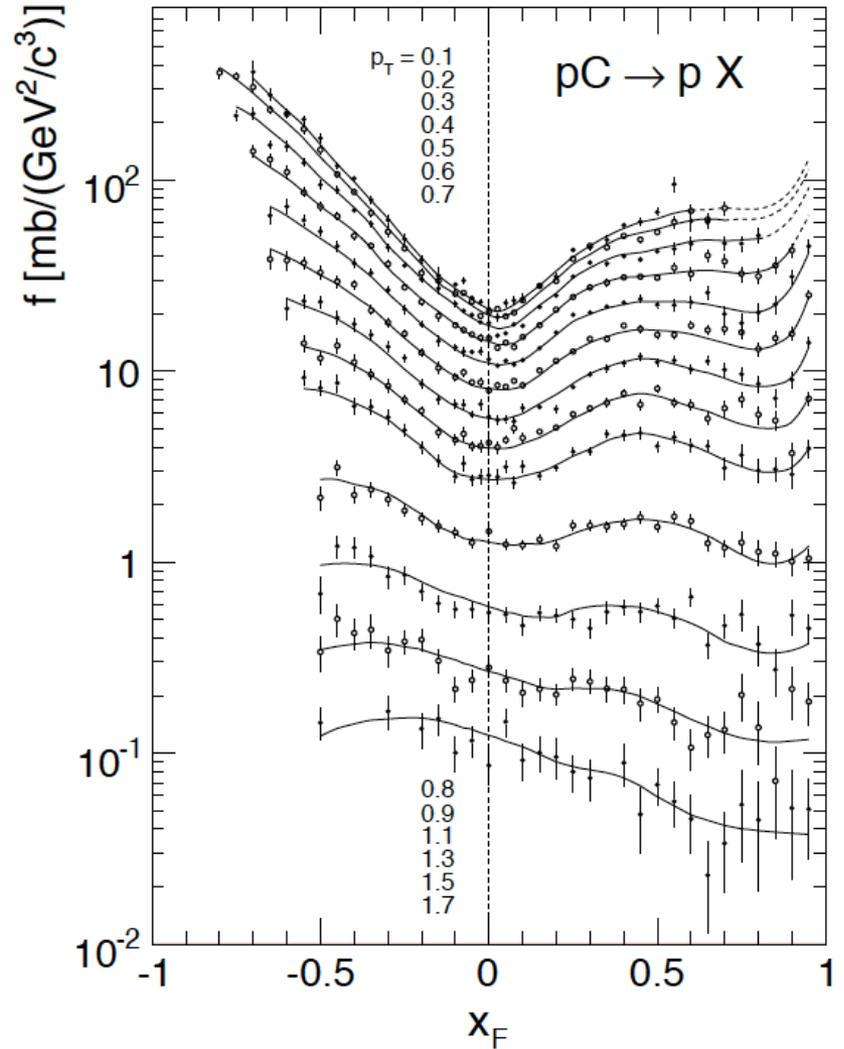
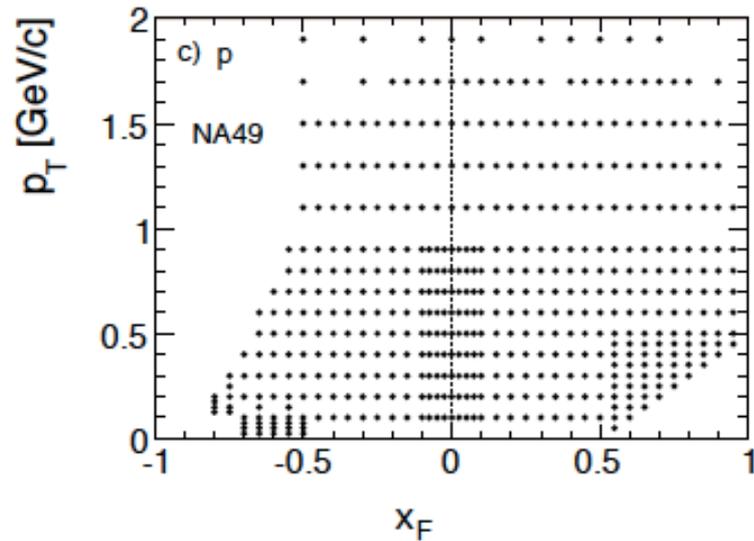
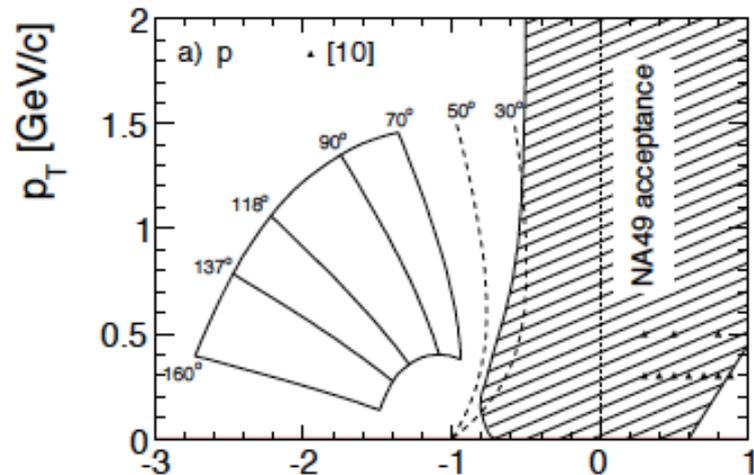
(from D. Schmitz)

# Existing Proton-C $\pi$ Production



- NA49 data at 158 GeV/c
  - Probably the best data available nearby 120 GeV but must be extrapolated to lower energy
  - *Lacks very forward production  $x_F > .5$*

# NA49 Proton Data at 158 GeV/c



# In T2K, Secondary Nucleon Errors Dominate Flux Uncertainties

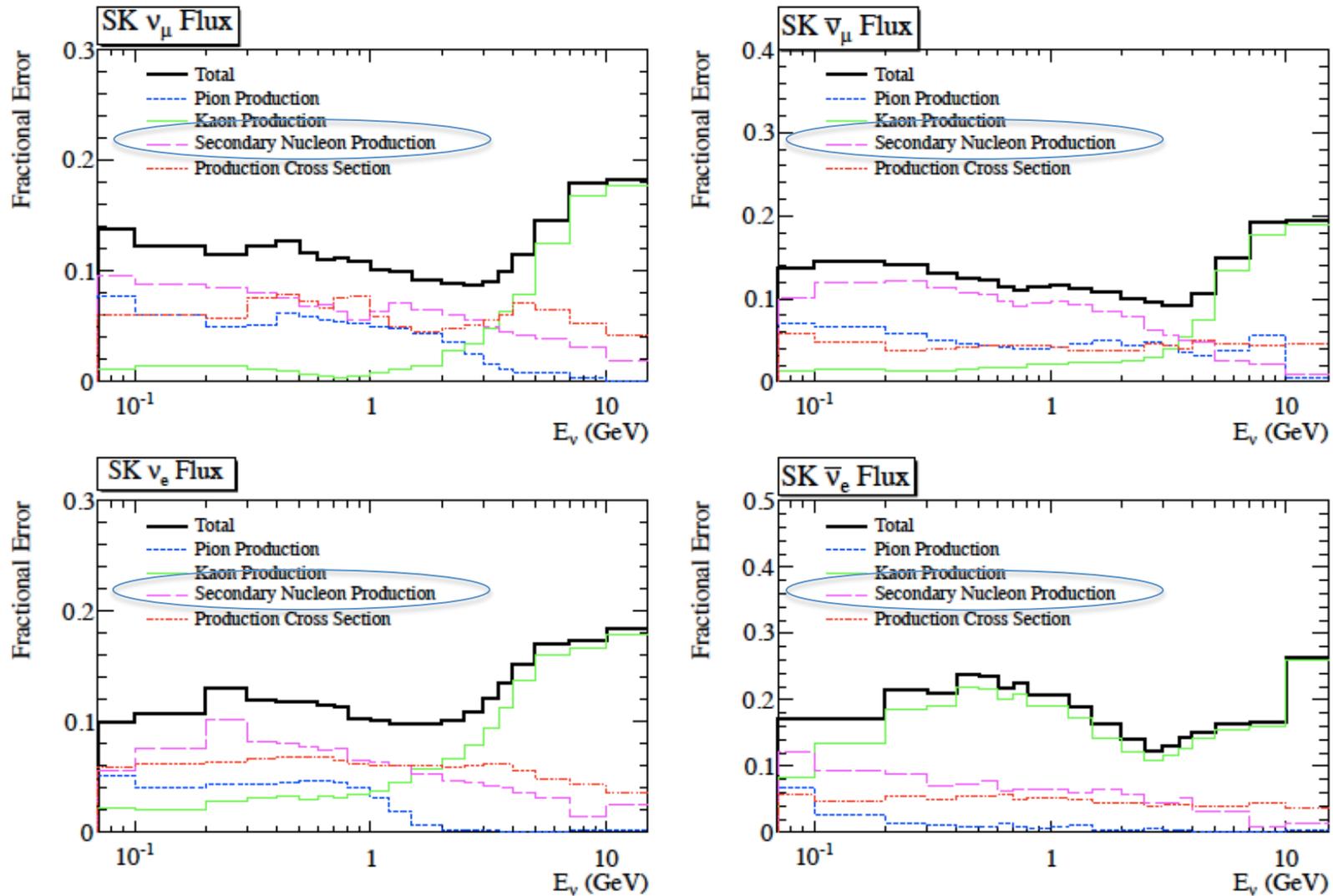


FIG. 38: Fractional flux error due to hadron production uncertainties.

# T2K Secondary Nucleons

- Secondary protons and neutrons that yield productive mesons in T2K target

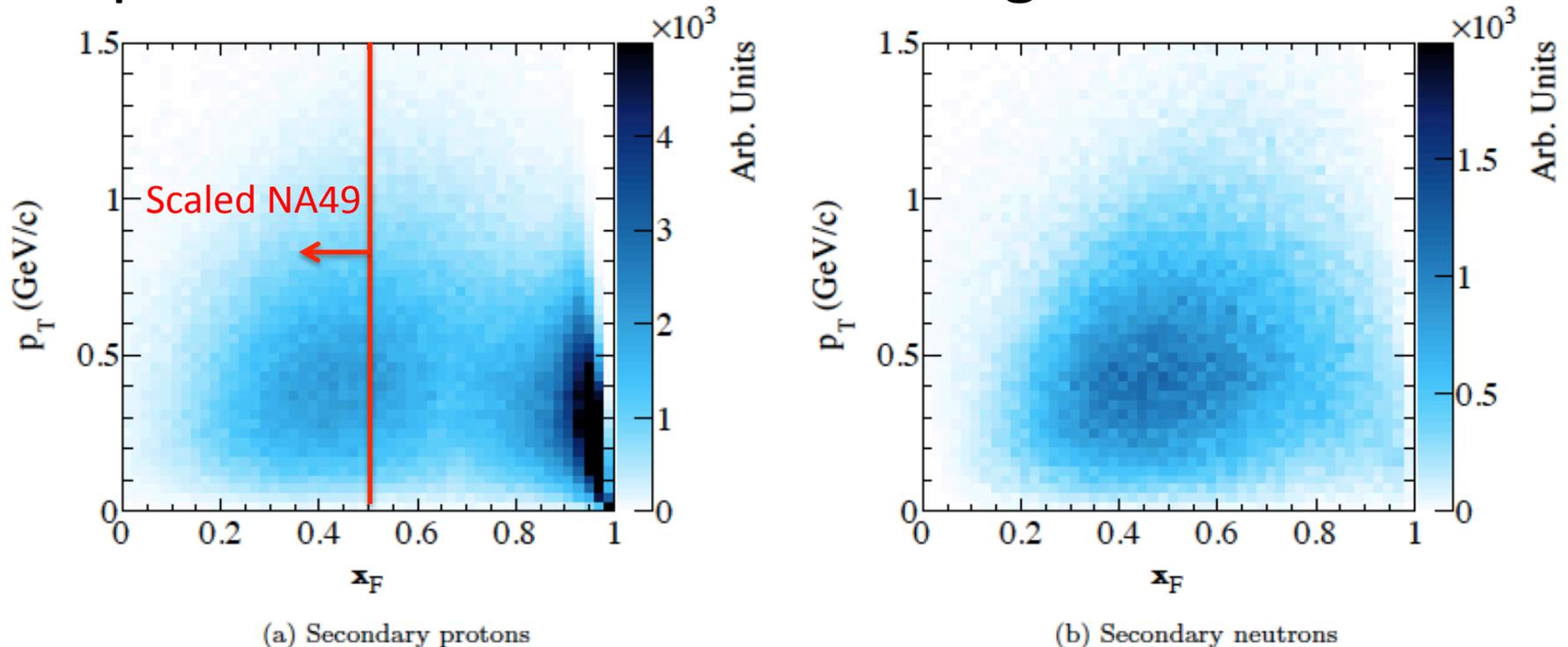
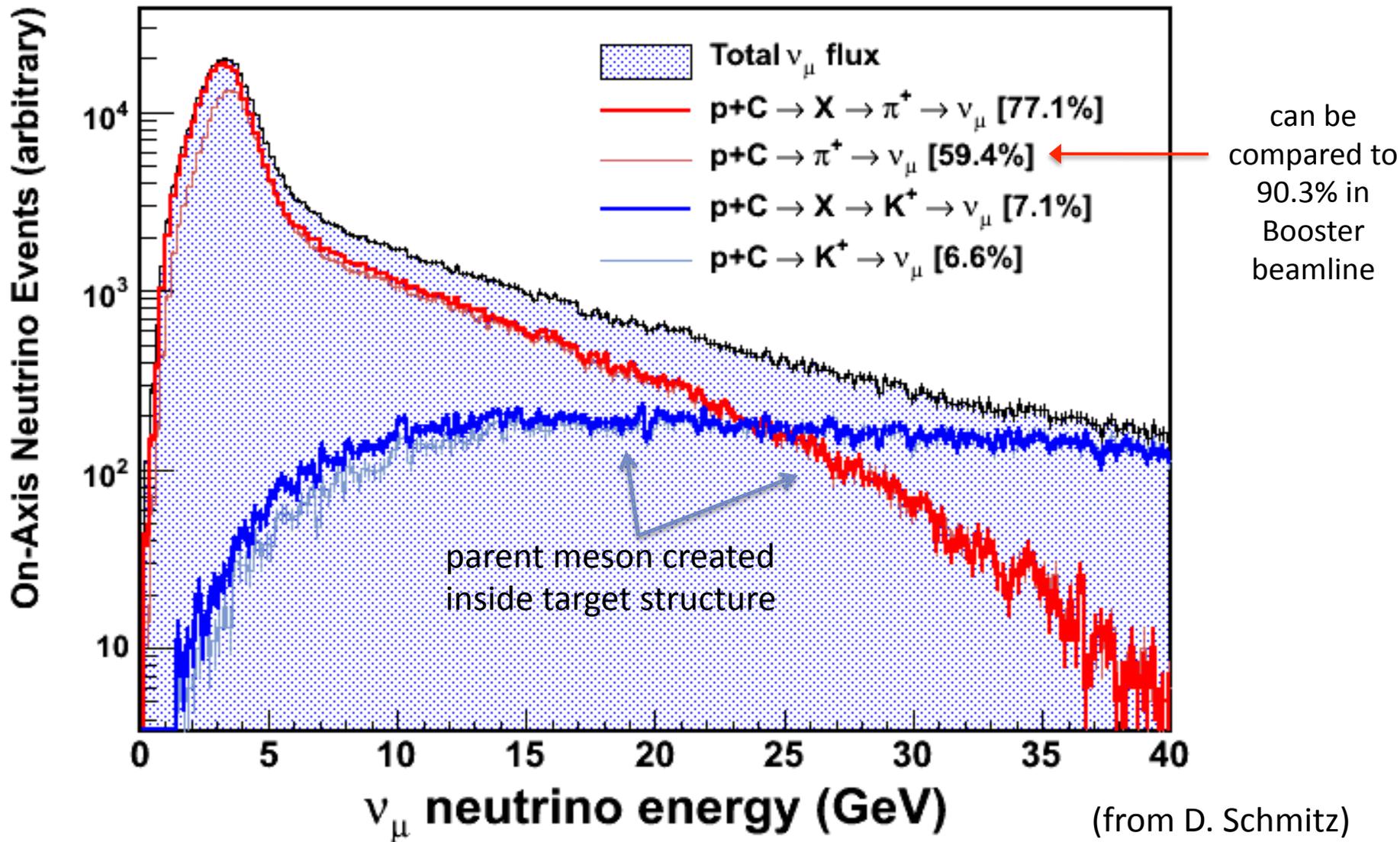


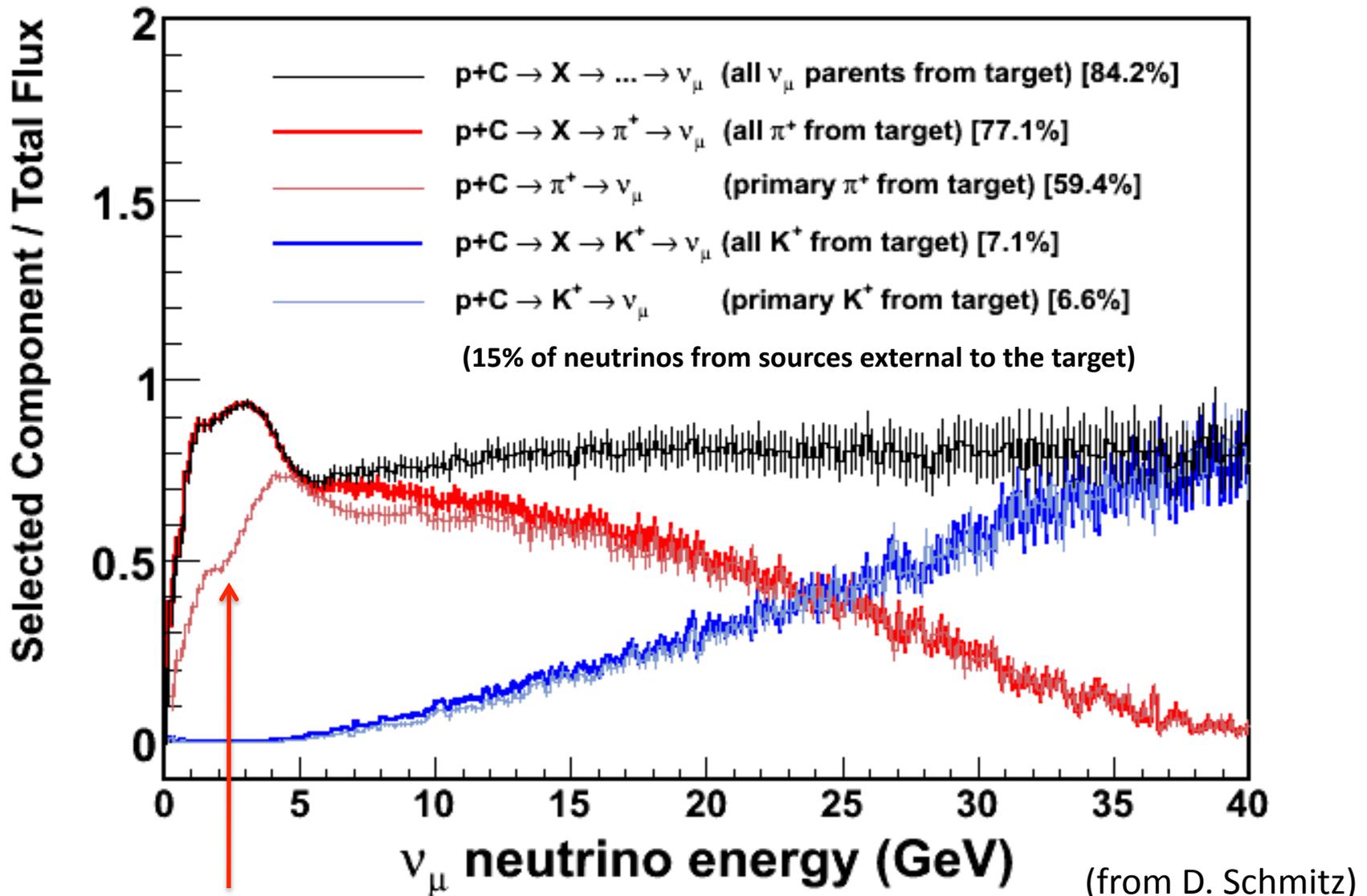
FIG. 35: Distribution of secondary protons and neutrons contributing to the neutrino flux at SK, evaluated with the FLUKA hadron interaction model.

# NuMI Flux



(from D. Schmitz)

# Fractional NuMI Fluxes

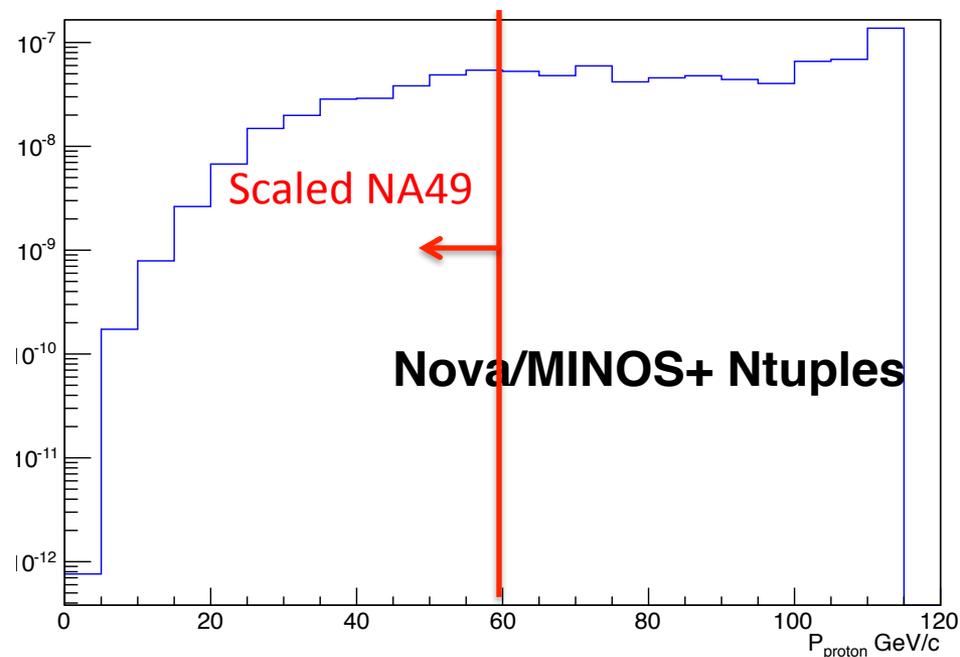


This is the piece one directly constrains with the NA49 data, though in a model dependent way since it is extrapolated 158 GeV/c

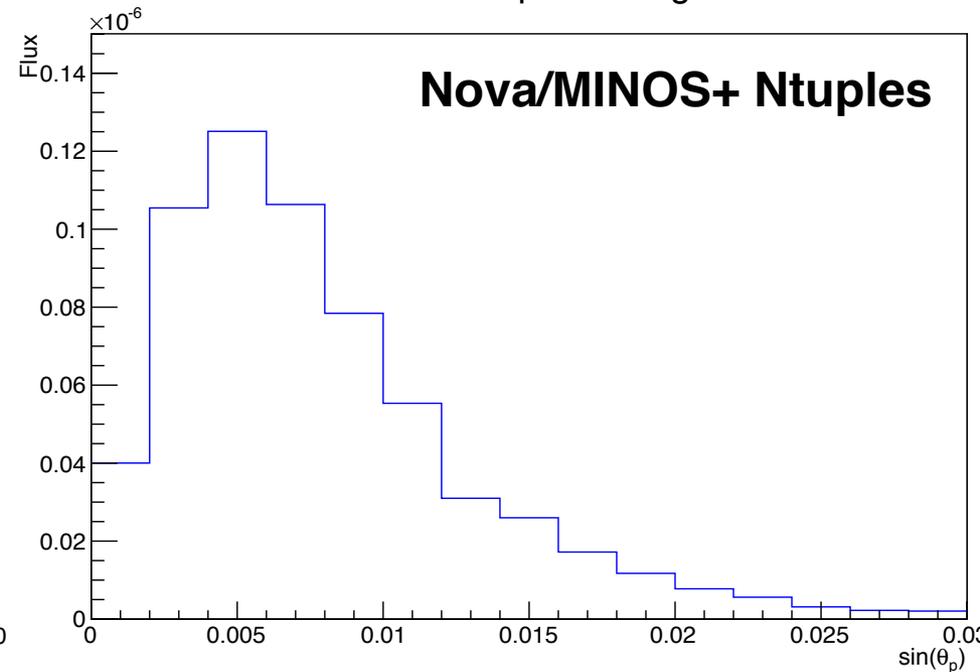
# Thin target secondary protons

- Proton rates weighted by flux contribution

Productive proton momentum



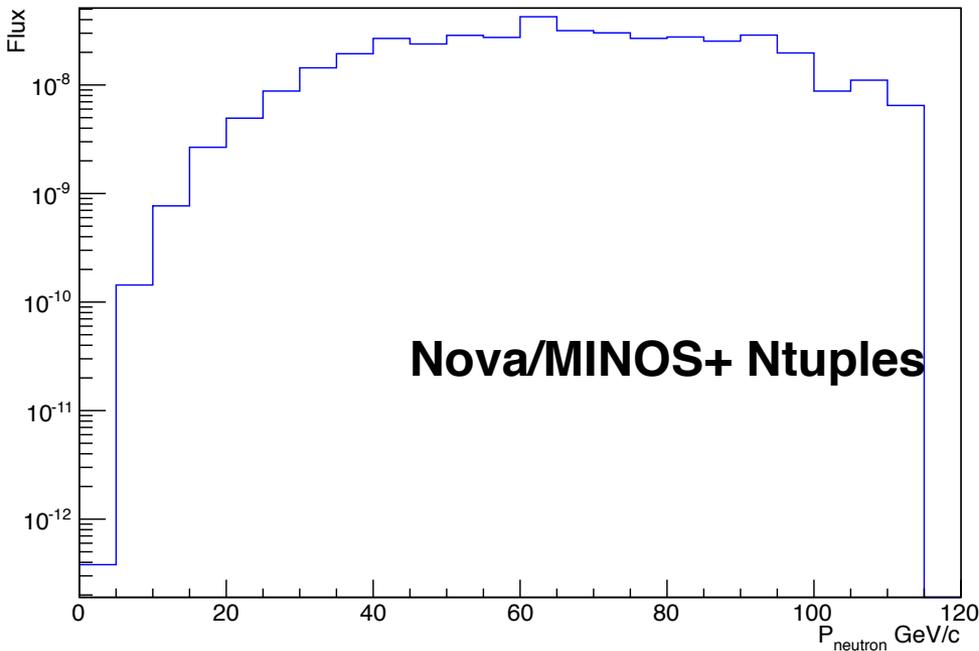
Productive proton angle



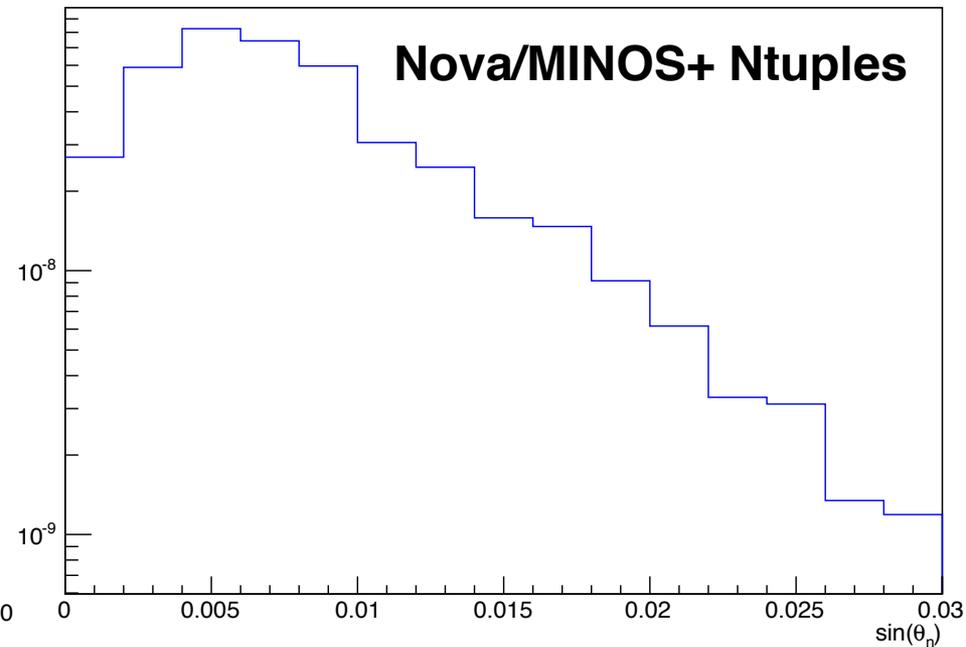
# Thin target secondary neutrons

- Neutron rates weighted by flux contribution

Productive neutron momentum



Productive neutron angle



# USNA61 Proposal

- Pilot run in 2012
  - 3.5 M triggers at 120 GeV, analysis in progress
- Small upgrade for 2014-2015 runs
  - Electronics upgrade for TOF counters
    - Vittorio Paolone, U. Pitt., Sandro Bravar, U. Geneva
    - ~ 3000 channels of DRS4 TDC's
  - Forward Tracking
    - Eric Zimmerman, U. Colo.
    - 2 or 3 small forward TPCs to cover far-forward region
- 4-6 weeks of data in 2014 and 2015

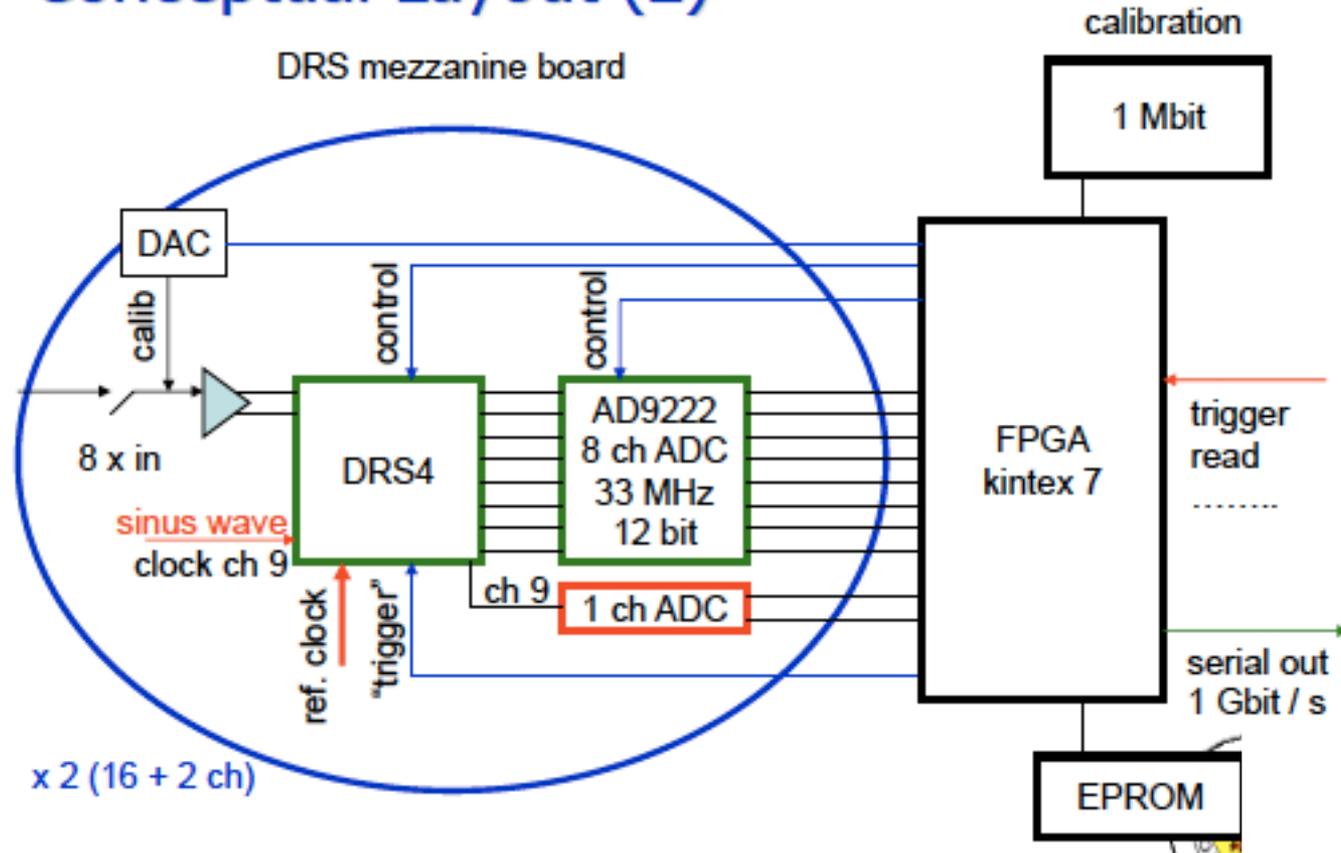
# Electronics Upgrade

## Overall structure

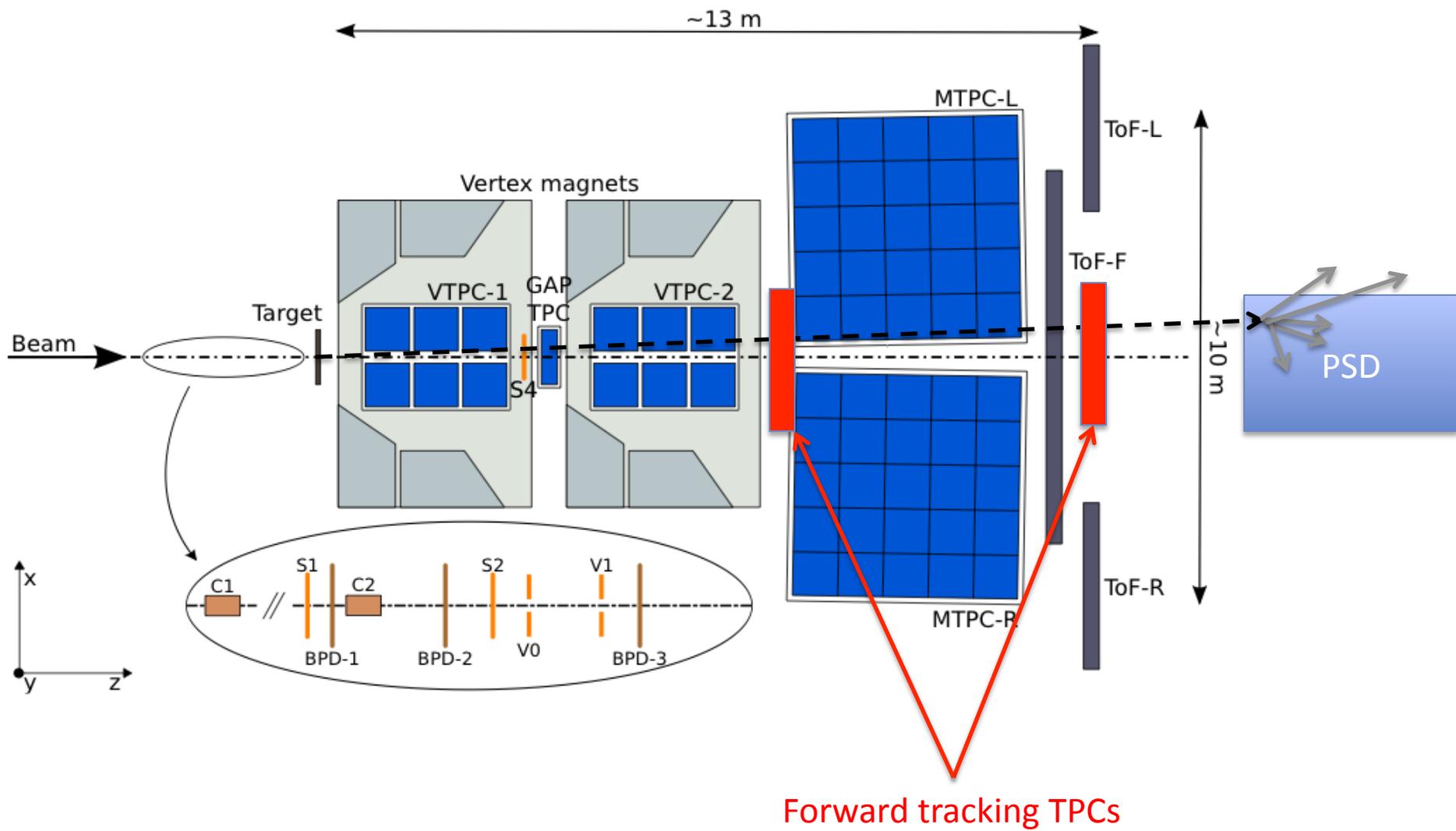
tentative design : 16 channels / DRS mezzanine board 64 channels / DRS mother board		board = 16 ch
ToF-L + ToF-F(L)	(56 + 5 boards @ 5 GHz)	DDL
ToF-R + ToF-F(R)	(56 + 5 boards @ 5 GHz)	DDL
PSD	(28 boards @ 1 GHz)	DDL
BPD	(9 boards @ 0.5 GHz)	} DDL
Beam	(2 boards @ 5 GHz)	
Beam (scalers, registers)		VME
~ 2600 channels + spares		

# Tentative DRS4 Design

## Conceptual Layout (2)



# NA61 Detector



# Forward Tracking

- Would provide accurate measurement of forward protons  $0.5 < x_F < 1$
- Protons would in turn provide a calibration for neutron measurement with PSD
- Would provide accurate anchor point for TPC calibration which now relies on TOF-L/R

# Preliminary USNA61 Run Plan

proton+pion event totals	Incident proton/pion beam momentum			
Target	120 GeV/c	90 GeV/c	60 GeV/c	30 GeV/c
NuMI (spare) replica	2M			
LBNE replica	2M			
thin graphite ( $< 0.05\lambda_I$ )	2M	2M	2M	-
thin aluminum ( $< 0.05\lambda_I$ )		2M	2M	2M
thin steel ( $< 0.05\lambda_I$ )		2M	2M	2M
thin beryllium ( $< 0.05\lambda_I$ )	2M	2M	2M	2M
thin concrete ( $< 0.05\lambda_I$ )		2M	2M	2M

# REFERENCE SLIDES